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ABSTRACT

This study attempts to evaluate procedures for studying hemispheric differences in newborn human infants and to determine what acoustic characteristics of speech sounds will trigger a left hemisphere (LH) response. Within 48 hours of birth, 14 neonates were individually administered five aural stimuli which comprised two speech syllables, two nonspeech stimuli, and a 500 Hz tone. These stimuli were presented individually to the infants, and corresponding auditory evoked potentials (AEP) were measured by means of recording electrodes on left and right temporal areas of the infant's brain. Factor analysis was used to isolate the minimum number of AEP components which accounted for the majority of the variance. Four factors were found which together accounted for 96% of the variance. The results offer further evidence to support the idea that hemispheric differences are present during early infancy and that there are AEP differences between male and female infants. Although the study failed to demonstrate acoustic factors which trigger differential hemispheric responding, discrete components of the AEP responses were identified which were responsive to specific aspects of the acoustic stimuli. Information concerning temporal differences in the processing of these elements was also obtained.
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Cerebral Assymetry: Changes in factors affecting its development

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During the past century a great deal of research has focused on the relationship between language abilities and hemisphere functions. The results of these efforts suggest that many language abilities may be controlled by mechanisms within the left cerebral hemisphere while the right hemisphere may control quite different functions in the adult human brain. However, although the presence of such relationships have long been studied in adults, researchers have only recently turned their attention to the development of the hemispheric differences in infants and children. To date a number of researchers employing remarkably diverse procedures have reported finding some indications of hemispheric differences within the first year of life. Such procedures have included the use of evoked potential recording techniques (1,2,3,4,5), photic driving procedures (6, 7), EEG power distributions analyses (8, 9), anatomical analyses (10, 11), and dichotic listening procedures (12). This paper will briefly review the use of electrophysiological techniques to assess hemispheric differences and then will report several recent attempts by our lab to isolate the acoustic determinants of laterality.

An early indication of hemispheric differences in infants was reported by Molfese (1, 13). Molfese recorded the auditory evoked potentials (AEP) of 10 infants (mean age: 5.8 months), 11 children (mean age: 6 years) and 10 adults (mean age: 25.9 years) to a series of speech syllables, words, a piano

chord and a white noise burst. Twenty-seven of the 31 subjects responded to the speech material with a larger amplitude left hemisphere (LH) evoked potential. Thirty subjects responded to the piano chord with the largest amplitude change occurring in the right hemisphere (RH), and 29 subjects responded to the white noise stimulus with the largest AEP occurring in the RH. The proportion of subjects who responded with differential hemispheric activity did not differ across age groups. This was interpreted as support for the hypothesis that hemispheric differences are present during infancy. A recent AEP study conducted by Barret, de Sotillo & Compos (5) with marasmic and normal infants generally supports these earlier findings. They presented a series of clicks and a second series containing repetitions of the child's own name to a group of infants ranging in age from 5 to 12 months (mean age: 8 months). The AEPs were recorded from the anterior parietal locations C₃ and C₄ from the left and right hemispheres respectively. When the hemisphere responses of the normal children were compared, 11 of 16 comparisons showed a LH predominance while three reflected a larger RH response. A clear RH amplitude predominance emerged from the infants responses to the click stimulus.

Several other procedures have been employed to assess hemispheric differences in infants. Gardiner, Schulman & Walter (8) and Gardiner & Walter (9), analyzing changes in the EEG power distributions, reported finding hemispheric differences in 4 six-month old infants in response to continuous segments of speech and music. The infant EEGs were recorded from four locations over each hemisphere and referred to linked mastoid electrodes. The EEG epochs were recorded from stimulus onset to offset. Continuous plots of the laterality ratio versus time for each pair of symmetrical channels were then calculated for each epoch. Only the parietal and temporal locations (P₃ - P₄ and W₁ - W₂ respectively) yielded hemisphere differences with the largest changes occurring at the W leads. For all infants, the power spectrum between 3 and 5

hertz (Hz) decreased at the LH leads during the speech condition and at the RH leads during the music condition.

Hemispheric differences have also been found in response to visual stimuli. Crowell, Jones, Kapuniai & Nakagawa (6) found evidence of differential hemispheric driving in the right hemisphere of newborn human infants in response to presentations of rhythmic visual stimuli. Subjects were 97 newborn fullterm infants. Crowell et al. placed electrodes over the left and right occipital areas (O_1 and O_2 respectively) and referred these areas to the right ear. Repetitive light flashes were presented at 3 per second for 4 seconds. Recorded responses were later tested for photic driving -- an increase in the EEG spectral frequency to the same frequency as the stimuli. Photic driving was found in 36 infants (37% of the total). Of these infants, 50% showed unilateral driving. Sixteen infants showed greater activity in the RH while two infants had more activity in the LH. Eighteen infants showed bilateral driving. Given that adults in a similar situation typically show bilateral driving, the presence of unilateral driving was thought to be due to a more advanced development of the RH occipital area.

A more recent study by Crowell, Kapuniai & Garbanati (7) with 217 infants supported these earlier findings for unilateral driving and reported a decrease in asymmetrical responding with age. At two days of age, 12% of the infants showed bilateral driving while at 30 days, 48% of the infants had bilateral driving. This decrease in differential hemispheric responding may be comparable to that reported by Molfese (2) and Molfese, Freeman & Palermo (4). They reported that the degree of laterality, as indicated by amplitude differences of the AEPs, was greater in the infants than in the adults in response to both the speech syllables and the nonspeech stimuli. The authors hypothesized that such decreases in laterality might be due to changes in the corpus callosum

and various commissures which interconnect the two cerebral hemispheres (14).

All the studies reviewed report the presence of hemispheric differences during infancy. Interestingly, all those studies involving auditory stimuli were generally consistent in their findings that speech materials and nonspeech stimuli such as click, white noise burst and music produced differential hemispheric responding in infants (1,2,3,4,5,8,9,13).

Given that infants at birth are generally thought to have only a reflex-based cognitive system (15) and little or no linguistic skills (16) it would appear that the asymmetrical responses of infants to auditory stimuli must be based at least initially on certain physical characteristics of the acoustic stimuli. However, researchers have only recently turned their attention towards this problem. Cutting (17) in a study with adults isolated several elements which triggered differential hemispheric responding. Using a modified dichotic listening procedure, Cutting presented a series of vowel (non-transition) and consonant-vowel (transition) syllables which were synthesized with either narrow bandwidth formants or with "normal" formants. Cutting reported that both the broadband and transition stimuli resulted in a right ear advantage (greater LH than RH processing) while the narrow bandwidth and nontransition stimuli did not elicit any differences between hemispheres. In an attempt to assess the contribution of these acoustic elements in eliciting differential hemispheric activity in infants, Molfese (3) presented stimuli similar to those employed by Cutting to a group of 16 newborn infants. Half of the stimuli contained a transitional element and half were steady state sounds. Of these sounds, half were composed of three formants with bandwidths comparable to those for speech and half with bandwidths of only 1 Hz. The AEPs were recorded from the T₃ and T₄ electrode locations and referred to linked ear lobes (18). An analysis of the amplitude changes across hemisphere

and stimulus conditions indicated that bandwidth was a determining factor for producing hemisphere differences. When a normal bandwidth stimulus was presented, a larger amplitude AEP occurred in the LH than in the RH. However, when a narrow bandwidth stimulus was presented, the RH amplitude change was larger than that for the LH. The presence of transitional elements did not appear to have any effect on the AEP amplitude across hemispheres. Consequently, it was concluded that bandwidth rather than transitional elements was a critical acoustic element responsible for triggering differential hemispheric activity. However, these analyses, like those for many EP studies, involve only a relatively small proportion of the AEP response. In this case, only two time points out of nearly 200 were set aside for analysis while the bulk of the data was discarded. If the AEP does reflect changes in brain processing over time as some writers have suggested (19), the analysis of the entire waveform over time would be of critical importance in attempts to understand the underlying processes which generate these waveforms. Recently, a technique has been developed which not only allows one to analyze the entire waveform, but in addition, allows for the possibility of identifying the processes reflected by different components of the evoked potential waveform (20).

The following study represents initial attempts to evaluate the suitability of such analyses for studying hemispheric differences in newborn human infants. This study, like (3), was again designed to assess what acoustic characteristic of speech sounds would trigger a LH response. The work of Molfese (3) and Cutting (17) both suggested that bandwidth was a decisive factor in triggering LH processing. Although Molfese had not found any indication that transitional elements were critical to lateralization of responses, it was hypothesized that the measure used (AEP amplitude) may not

have been sensitive enough to this manipulation. Given the continuous nature of the AEP response, the transition element could have been coded in another part of the AEP waveform. If the factor analysis would be sensitive to changes throughout the AEP, perhaps it could isolate such an element. An additional acoustic stimulus, a pure tone was added to assess possible contributions to a lateralized response by number of formants.

Method

Subjects. Fourteen neonates (seven males and seven females) were tested within 48 hours of birth. Mean birth weight was 7.01 lbs (range: 5.90 - 8.47) for males and 7.19 lbs (range: 5.00 - 8.30) for females. Demerol was the chief anesthetic administered to the mother during labor. Two infants (one male and one female) were delivered by Caesarian section.

Stimuli. Five sounds were used as stimuli: two synthetically produced speech syllables *gæ* and *æ* and two nonspeech stimuli which were constructed from pure tones corresponding exactly to the central frequencies of the formants for the speech syllables. These stimuli were constructed by Dr. James Cutting on the parallel resonance synthesizer at the Haskins Laboratories. For additional information concerning the construction of the stimuli, the reader is referred to Cutting (17). A fifth stimulus, a 500 Hz tone, was also presented. This stimulus was similar to the *æ* syllables in that it was a steady state sound. However, it was composed of one formant rather than three and the formant bandwidth was 1 Hz. The four multiple formant stimuli are depicted in Figure 1. The broadband "speech" stimuli are presented on the left side of the figure while

Insert Figure 1 about here

the narrow bandwidth nonspeech stimuli are on the right. The formants of the broad band stimuli were 60, 90, and 120 Hz in width for formants 1, 2, and 3 respectively. All formants of the narrow band stimuli were 1 Hz in width. Both stimuli at the top of the figure contain transitional elements which generally characterize a consonant sound. Two steady state sounds which typify vowel sounds are at the bottom of the figure. All stimuli were 300 msec in duration and were presented at equal peak intensity levels.

Twenty random orderings of these stimuli were recorded on one channel of a stereo tape recorder. The time interval between stimuli was randomly varied between 4 and 8 seconds. A 50 Hz square wave was recorded on a second channel of the tape recorder 30 msec before each stimulus. This pulse served as a signal to a PDP-12 computer to begin averaging the AEPs.

Procedure. Each infant was tested individually in a room adjoining the hospital nursery. The infant was placed in a semi-reclined infant seat and scalp electrodes were placed over the left and right temporal areas (T_3 and T_4 respectively). These electrodes were referred to linked ear leads. A fifth recording lead was placed on the forehead to serve as a floating ground. A mean resistance of 4.55 k Ω was maintained throughout the testing. The electrodes were then plugged into two isolation amplifiers (Analogue Devices, model 273J). This output was connected to 2 modified differential amplifiers (Tektronix AM 502) with the bandpass flat between .1 and 30 Hz. After approximately a 5 minute period had elapsed following application of the recording electrodes, the stimuli were presented. The AEPs elicited in response

to these sounds were recorded on a Cassette FM tape recorder (Vetter model C-4). These responses were later averaged on a PDP - 12 computer.

Data analyses. Following Chapman, McCary, Bragdon, and Chapman (20), the data analyses were performed using factor-analytic and analysis of variance techniques. The raw data consisted of 140 EP measurements in microvolts (μV) obtained from both hemispheres of 14 infants, during 5 experimental conditions. A 70 (variables) x 140 (cases) input data matrix was obtained from these 140 EP measurements by taking the recordings at each of 70 time points (with an interval of 13 msec) from each EP measurement over a 900 msec period. Intercorrelations among the 70 variables were submitted to principal components analysis, and factors with eigen values greater than 1.0 were rotated using the varimax method (21, 22), with the BMD x 72 computer program (23). This was done to obtain latent components of EP's, which would provide a parsimonious representation of complex data.

To obtain exact temporal and amplitude measures of the factors, it was necessary to convert the factors to the original metric (microvolts). The rotated factors were expressed by multiplying the factor loading at each time point first with the standard deviation of all EP values at that point, and then with the factor score appropriate for a particular stimulus condition. For interpreting each factor, factor scores were submitted to mixed design analysis of variance (24) using the BMD 08V computer program (23).

Results

Four factors accounted for 96.08% of the total variance. The centroid (the average EP of the entire data set) and the four factors (in the original

metric) are plotted in Figure 2.

Insert Figure 2 about here

Factor 1, was characterized by a negative going waveform which peaked approximately 600 msec after stimulus onset. Factor 2 was marked by a late positive wave which reached its peak 884 msec following stimulus onset. Factor 3 was initially characterized by a negative deflection which peaked 533 msec after stimulus onset and a subsequent positive wave which reached its maximum at the end of the 900 msec period. Factor 4 was characterized by an initial positive wave which peaked after 300 msec. This was followed by a negative wave which peaked at 624 msec and a subsequent smaller positive peak at 832 msec.

Analyses of variance were performed to investigate the effects of four independent variables (sex, hemisphere, transition, bandwidth) on each of the four factors.

Factor scores were first analyzed by a 2(sex) x 2(hemisphere) x 2(bandwidth) x 2(transition) analysis of variance. A significant main effect for sex ($F = 4.75$, $df = 1, 12$, $p < .05$) was present for factor 1. A significant transition effect ($F = 5.28$, $df = 1, 12$, $p < .05$) indicated differences between the gæ stimuli and the æ stimuli for factor 2. A significant hemisphere effect ($F = 6.66$, $df = 1, 12$, $p < .05$) revealed differential hemispheric responding for factor 4. Inclusion of the fifth stimulus, the 500 Hz tone, resulted in a

2(sex) x 2(hemisphere) x 5(stimulus condition) design. An analysis of variance indicated no significant main effects. Using Scheffe' planned comparison tests, in which the tone was grouped first with the steady state stimuli and then with the narrow bandwidth stimuli, the transition and bandwidth variables were further examined. A significant transition effect ($F = 4.34$, $df = 1, 48$, $p < .05$) was represented by factor 2 and a significant bandwidth effect ($F = 4.40$, $df = 1, 48$, $p < .05$) was reflected by factor 3.

A group averaged AEP and four factors were then reproduced for each stimulus for both hemispheres. The group AEP and the four factors elicited in response to ga_{ss} are shown in Figure 3. The group AEPs at the top of the figure

Insert Figure 3 about here

reflect an overall amplitude difference between hemispheres with a larger AEP occurring in the LH than in the RH in response to this broadband, transitional speech syllable. The LH response was approximately 6.5 μV larger than the RH. Factor 1 reflected the sex difference in the AEPs of newborn infants; therefore, discussing its differences across hemispheres and stimuli is of little value and will not be developed in this or the following figures. Factor 2, which was sensitive to steady state (non transition) elements, was characterized by a late positive component for the RH but almost no change in potential for the LH. Factor 3, which differentiated between narrow and broadband stimuli was characterized by a negative deflection. Factor 4, which reflected hemisphere differences, was represented by components which were opposite in polarity for the two hemispheres.

Insert Figure 4 about here

Figure 4 represents the group AEPs and factors elicited in response to æ_{ss} - a steady state, broad bandwidth stimulus. A larger change in AEP amplitude (16 μV) occurred in the LH than in the RH in response to this stimulus. In contrast to factor 2 for gæ_{ss} , the LH was marked by a large positive waveform. The RH component was similar to that for the gæ_{ss} stimulus. As indicated earlier, factor 2 occurred when a steady state stimulus was presented. Factor 3 was again marked by a negative going waveform for a broadband stimulus. Hemisphere differences are again reflected by the opposite polarities of factor 4.

The group AEPs and components elicited in response to gæ_{sw} , a narrow bandwidth, transitional stimulus, are depicted in Figure 5. This stimulus differs from that of Figure 3 only in bandwidth. The RH amplitude of the

Insert Figure 5 about here

group AEP in response to this narrow band stimulus was approximately 47 μV larger than that for the LH. This is in contrast to the group AEPs elicited

in response to the two previous broadband stimuli. Factor 2 was characterized by a late positive wave for both hemispheres although the amplitude of the LH is greatly reduced from the level it reached for the preceding stimulus. Factor 3 was characterized by a positive waveform for both hemispheres. Factor 4 again reflected opposite polarities for the two hemispheres. In Figure 6, the group averaged AEPs and factors elicited in response to the narrow bandwidth,

Insert Figure 6 about here

steady state stimulus a_{sw} are presented. The RH group AEP was approximately 19 μV larger than the LH response. The LH was once again characterized by a large late positive deflection for factor 2 in response to a steady state stimulus. The RH was also marked by this late increasing component. Factor 3 was marked by a positive component in both hemispheres for this narrow band stimulus. Factor 4, however, was characterized by components with similar polarity in both hemispheres.

The group AEPs and factors elicited in response to the 500 Hz tone (a steady state, narrow bandwidth, single formant stimulus) are illustrated in Figure 7. The RH group AEP was approximately 12 μV larger in amplitude than the LH.

Insert Figure 7 about here

Factor 3, however, like that for the 2 preceding narrow bandwidth stimuli, was marked by a positive wave. The hemisphere polarities as reflected in factor 4 were again opposite to each other. Intriguingly, these polarities were opposite to those for the four other stimuli.

In general the degree of laterality as indicated by amplitude differences between hemispheres was approximately twice as great for the narrow bandwidth stimuli in the RH (mean amplitude difference = 26 μ V) than for broadband stimuli in the LH (mean amplitude difference = 11.25 μ V).

Discussion:

The use of the factor analysis to isolate the minimum number of AEP components which account for the majority of the variance appears to have been successful. Four factors were found which accounted for 96% of the total variance. The factor analysis also gave some indication of the temporal relationships between the different factors. Factor 1 occurred during the initial portion of the AEP; factor 2 increased over the final third of the response; and factor 3 was marked by a prominent wave midway through the AEP response. Factor 4 was the only factor which appeared to undergo change throughout the temporal period of the AEP. In light of these temporal differences, it would appear that the coding and processing of different experimental elements occurred at different times following stimulus onset.

Subsequent analyses demonstrated that each component did relate to specific characteristics of the experimental situation. Factor 1 reflected a sex difference. This factor differed between male and female infants across all stimulus conditions and appeared as a larger component in the female AEP responses. This could reflect a more advanced stage of neurological development for the female infants or a more general difference in the neurological processes between males and females. The former case is in agreement with several anatomical studies which report that some areas of the female cortex are developmentally more advanced than comparable areas in male infants (10, 11).

Factor 2 increased in amplitude when a steady state multiple formant stimulus was presented. However, a stimulus which contained a transition element in which a rapid change in frequency did occur (gæ) failed to elicit this factor. The presence or absence of a transitional element did not interact with hemispheres, that is, both hemispheres responded similarly to the absence of a transitional element. This finding is in contrast to Cutting's (17) report

that the presence of transitional elements produced a right ear (LH) advantage. This discrepancy may be due in part to developmental factors. Cutting tested adults while the work reported in the present study involved newborn infants. Consequently, it is possible that various developmental changes occurring between infancy and adulthood as a result of cognitive and neurophysiological factors might be responsible for these differences. A second factor which could account for such differences might be due to differences in the techniques employed. The electrophysiological procedures involved in monitoring AEPs in response to a set of stimuli might be assessing quite different cognitive or physiological correlates of these functions than the dichotic listening procedures of Cutting.

The polarity of factor 3 appeared to be dependent on the bandwidth of the stimulus. When a broadband stimulus was presented, factor 3 was characterized by a negative waveform while a positive waveform occurred in response to a narrow band stimulus.

Hemisphere differences were reflected in factor 4 by opposite polarities for the two hemispheres. The hemispheres of the newborn infants responded differently from each other to all stimuli. Although this is in agreement with earlier studies of hemisphere differences in infants, the lack of an interaction of hemisphere with transition or bandwidth suggests that no specific acoustic factor was responsible for producing the differential hemispheric activity reflected in factor 4. When the more traditional measures of hemispheric differences such as amplitude measures are considered, the situation becomes even more confusing. Several researchers have reported changes in AEP amplitude (1,2,3,4,5) or activity (6,7,8,9) across hemispheres as a function of different stimuli. Such differences have previously been interpreted as an indication of differential hemispheric involvement in the

processing of particular stimuli (25, 19). However, given that there was some overlap between the different factors in time, the amplitude or activity of the AEP at any single time point could reflect the influence of more than one factor. Thus the overall amplitude differences between the left and right hemispheres for the group AEPs (cf., Figures 3 - 7) could reflect the contributions of sex and stimuli factors in addition to the influence of the hemisphere differences. Consequently, the overall amplitude differences between hemispheres which have been previously reported may reflect both general differences in the types of processing available to each hemisphere (26) as well as differences in the utilization of more general mechanisms common to both hemispheres (27).

The failure of the present study to find acoustic factors which might trigger differential hemispheric responding may also be due to the limited nature of the stimuli. The one stimulus which appeared to affect the polarity of factor 4 was the 500 Hz tone. The polarity here for both hemispheres was the reverse of that for the first 4 stimuli. This stimulus, it was noted, differed from the other sounds in that it was composed of one formant rather than three. Perhaps if the number of formants were varied more systematically, some acoustic factors affecting laterality might emerge.

At this point, it no longer seems surprising to find indications of hemispheric differences in human infants even though less than a decade ago some individuals had argued that such differences would not appear until sometime between 2 and 3 years of age as the child develops his language skills (28). Nevertheless, questions still remain unanswered as to the role of cerebral asymmetry in language and cognitive functions. Lenneberg (28) had argued that man differed from lower organisms because of basic biological differences which allowed him to use language. A basic element which

contributed to these differences was lateralization. However, over the past several years researchers have found indications of such hemispheric differences in other species (29).

In a recent study conducted at the University of Konstanz (West Germany), Molfese, Freeman & Jones-Molfese (30) found indications of hemispheric differences in cats to stimuli which differed in bandwidth, transition, and number of formants. Bipolar recordings were made of AEPs over the primary auditory area (A1), the visual area (V18), and the insular temporal cortex (IT) across hemispheres. Only the insular temporal leads reflected a hemisphere difference. No differences between hemispheres occurred across the primary auditory or visual areas. An example of the AEP responses is presented in Figure 8. The AEPs elicited in response to both the broad band

Insert Figure 8 about here

and narrow band stimuli from the IT cortex are marked by positive deflections during the initial period following stimulus onset. Consequently, the two hemispheres responded differently to these stimuli. The visual area, however, was not characterized by such a deflection. The two hemispheres in this region were apparently responding in a similar fashion and no hemisphere differences were present. In addition, no changes in the direction of laterality appeared as a function of bandwidth. However, these data have not yet been submitted to the types of analyses used by the present authors in this paper. It is possible that the use of factor analytic techniques supplemented by other analyses might reflect some differences across hemispheres and stimuli. In

any case, it is clear that lateralization of function is not unique to man and therefore can not serve as a "biological sign" of human language abilities. Consequently, the specific role of hemispheric differences in determining or influencing language abilities remains open to speculation.

Summary

The present study offered further support for the notion that hemispheric differences are present during early infancy. Moreover, in addition to finding evidence of electrophysiological differences between male and female infants, discrete components of the AEP response were identified and isolated which were responsive to specific aspects of the acoustic stimuli. Information concerning temporal differences in the processing of these elements was also obtained.

References

1. MOLFESE, D. L. 1972. Cerebral asymmetry in infants, children and adults: auditory evoked responses to speech and music stimuli. Unpublished doctoral dissertation, The Pennsylvania State University.
2. MOLFESE, D. L. 1973. The development of hemispheric asymmetry for speech and non-speech stimuli. Paper presented to the Midwestern Psychological Association, Chicago.
3. MOLFESE, D. L. In press. The ontogeny of cerebral asymmetry in man: auditory evoked potentials to linguistic and non-linguistic stimuli. In Recent Developments in the Psychobiology of Language: The Cerebral Evoked Potential Approach. J. E. Desmedt, Ed. Oxford University Press. London.
4. MOLFESE, D. L., R. B. FREEMAN & D. S. PALERMO. 1975. The ontogeny of brain lateralization for speech and nonspeech stimuli. *Brain Lang.* 2: 356 - 368.
5. BARNET, A. B., M. V. DE SOTILLO & M. CAMPOS. 1974. EEG sensory evoked potentials in early infancy malnutrition. Paper presented at Society for Neuroscience, St. Louis.
6. CROWELL, D. H., R. H. JONES, L. E. KAPUNIAI & J. K. NAKAGAWA. 1973. Unilateral cortical activity in newborn humans: an early index of cerebral dominance. *Science.* 180: 205 - 208.
7. CROWELL, D. H., L. E. KAPUNIAI & J. A. GARBANATI. In press. Hemispheric differences in human infant rhythmic responses to photic stimulation. In Cerebral Evoked Potentials in Man. J. E. Desmedt, Ed. Oxford University Press. London.
8. GARDINER, M. F., C. SCHULMAN & D. O. Walter. 1973. Facultative EEG asymmetries in infants and adults. In Cerebral Dominance, BIS Conference Report. Vol. 34: 37 - 40.

9. GARDINER, M. F. & D. O. WALTER. In press. Evidence of hemispheric specialization from infant EEG. In Lateralization in the Nervous System. S. Harnard, R. W. Doty, L. Goldstein, J. Jaynes & G. Krauthamer, Eds. Academic Press. New York, N. Y.
10. WITELSON, S. F. & W. PALLIE. 1973. Left hemisphere specialization for language in the newborn: anatomical evidence for asymmetry. *Brain*. 96: 641 - 646.
11. WADA, J. A., R. CLARKE, A. HAMM. 1975. Cerebral hemispheric asymmetry in humans. *Arch. Neurol.* 32: 239 - 246.
12. ENTUS, A. K. 1974. Hemispheric asymmetry in processing of dichotically presented speech and nonspeech sounds by infants. Unpublished doctoral dissertation, McGill University.
13. MOLFESE, D. L. 1972. Cerebral asymmetry in infants, children, and adults: auditory evoked responses to speech and non-speech stimuli. Paper presented to the 84th meeting of the Acoustic Society of America, Miami.
14. SELNES, O. A. 1974. The corpus callosum: some anatomical and functional considerations with special reference to language. *Brain Lang.* 1: 111 - 139.
15. PIAGET, J. 1970. Piaget's theory. In Carmichael's Handbook of Child Psychology. P. Mussen, Ed. Vol. 1: 703 - 732. John Wiley & Sons. New York, N.Y.
16. MACNAMARA, J. 1972. Cognitive basis of language learning in infants. *Psych. Rev.* 79: 1 - 13.
17. CUTTING, J. E. 1974. Two left-hemisphere mechanisms in speech perception. *Percept. Psychophys.* 16: 601 - 612.
18. JASPER, H. H. 1958. The ten-twenty electrode system of the international federation of societies for electroencephalography: Appendix to report of the committee on methods of clinical examination in electroencephalography. *Electroencephalogr. Clin. Neurophysiol.* 10: 371.

19. REGAN, D. 1972. Evoked Potentials in Psychology, Sensory Physiology and Clinical Medicine. John Wiley & Sons, Inc. New York, N.Y.
20. CHAPMAN, R. M., J. W. MCCRARY, H. R. BRAGOON, J. A. CHAPMAN. In press. Latent components of evoked potentials functionally related to information processing. In Cerebral Evoked Potentials in Man. J. E. Desmedt, Ed. Oxford University Press. London.
21. HARMAN, H. H. 1967. Modern Factor Analysis. 2nd edit. University of Chicago Press. Chicago, Il.
22. MULAİK, S. A. 1972. The foundation of factor analysis. McGraw - Hill. New York, N.Y.
23. DIXON, W. J. Ed. 1972. BMD Biomedical Computer Program: X-series supplement. University of California Press. Berkeley, California.
24. MYERS, J. L. 1972. Fundamentals of experimental design. 2nd edit. Allyn & Bacon. Boston, Mass.
25. BARNET, A. B. & A. LODGE. 1967. Click evoked EEG responses in normal and developmentally retarded infants. Nature. 214: 252 - 255.
26. NEBES, R. D. 1974. Hemisphere specialization in commissurotized man. Psychol. Bull. 81: 1 - 14.
27. BROADBENT, D. E. 1974. Division of function and integration of behavior. In "Neurosciences: IIIrd Study Programs" (F. O. Schmitt & F. C. Worden, Eds.), 31 - 42. MIT Press, Cambridge, Mass.
28. LENNEBERG, E. H. 1967. Biological foundations of language. John Wiley & Sons. New York, N.Y.
29. WEBSTER, W. G. 1972. Functional asymmetry between the cerebral hemispheres of the cat. Neuropsychol. 10: 75 - 87.
30. MOLFESE, D. L., R. B. FREEMAN, Jr., & V. J. JONES-MOLFESE. 1975. Electrophysiological indices of hemispheric differences in cats. In preparation.

Figure Headings

Figure 1. The acoustic structure of the syllables gæ and æ. Stimuli with normal broad band formant structure are on the left of the figure and narrow band sinewave structure are on the right. Stimuli with transitions (gæ) are represented at the top of the figure while steady state stimuli (æ) are at the bottom. All stimuli were 300 msec. in length. (After Cutting, 17).

Figure 2. Centroid and four factors over all stimulus conditions. The centroid at the top is the average EP of the entire set of data. The calibration scale is 10 µV. Below are the four factors obtained from the varimax principal components analysis and returned to the original metric. In this and all other figures positive is up and the time course is 900 msec.

Figure 3. Reproduced EPs and factors for stimulus condition gæ_{ss}. For this and the following figures the left hemisphere plots are shown on the left and those for the right hemisphere on the right. The four factors for each hemisphere were obtained from the rotated factor loadings returned to the original metric and multiplied by the factor score for that condition. Consequently factors in the two hemispheres differ only by their appropriate condition factor scores. The reproduced EPs shown at the top are the sums of the four factors plus the centroid. At the right is a 20 µV calibration scale.

Figure 4. Reproduced EPs and factors for stimulus condition æ_{ss}.

Figure 5. Reproduced EPs and factors for stimulus condition gæ_{sw}.

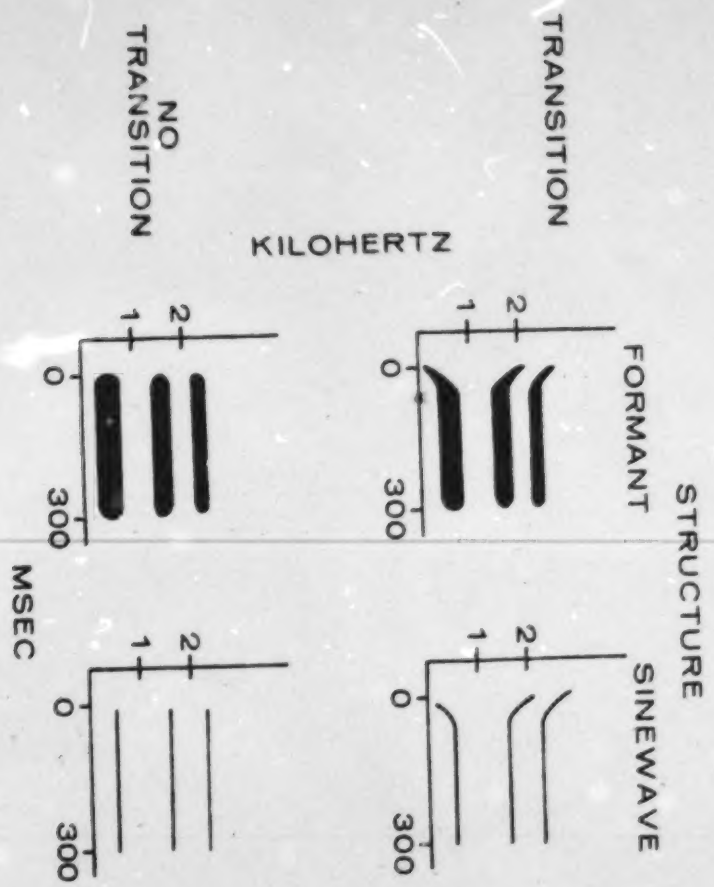
Figure 6. Reproduced EPs and factors for stimulus condition æ_{sw}.

Figure 7. Reproduced EPs and factors for stimulus condition Hz.

Figure 8. AEPs of Cat II to a broad band steady state vowel (σ_{ss}) and a narrow band steady state vowel (σ_{sw}). AEPs in response to σ_{ss} are depicted on the left and those to σ_{sw} are on the right. The top row of AEPs are responses recorded from the insular temporal region (IT) while responses from visual area 18 (V18) are presented at the bottom. AEPs were recorded for 500 msec following stimulus onset. The calibration is 30 μ V with negative up.

FOOTNOTES

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AVERAGED
EVOKED
POTENTIAL

10 μ V

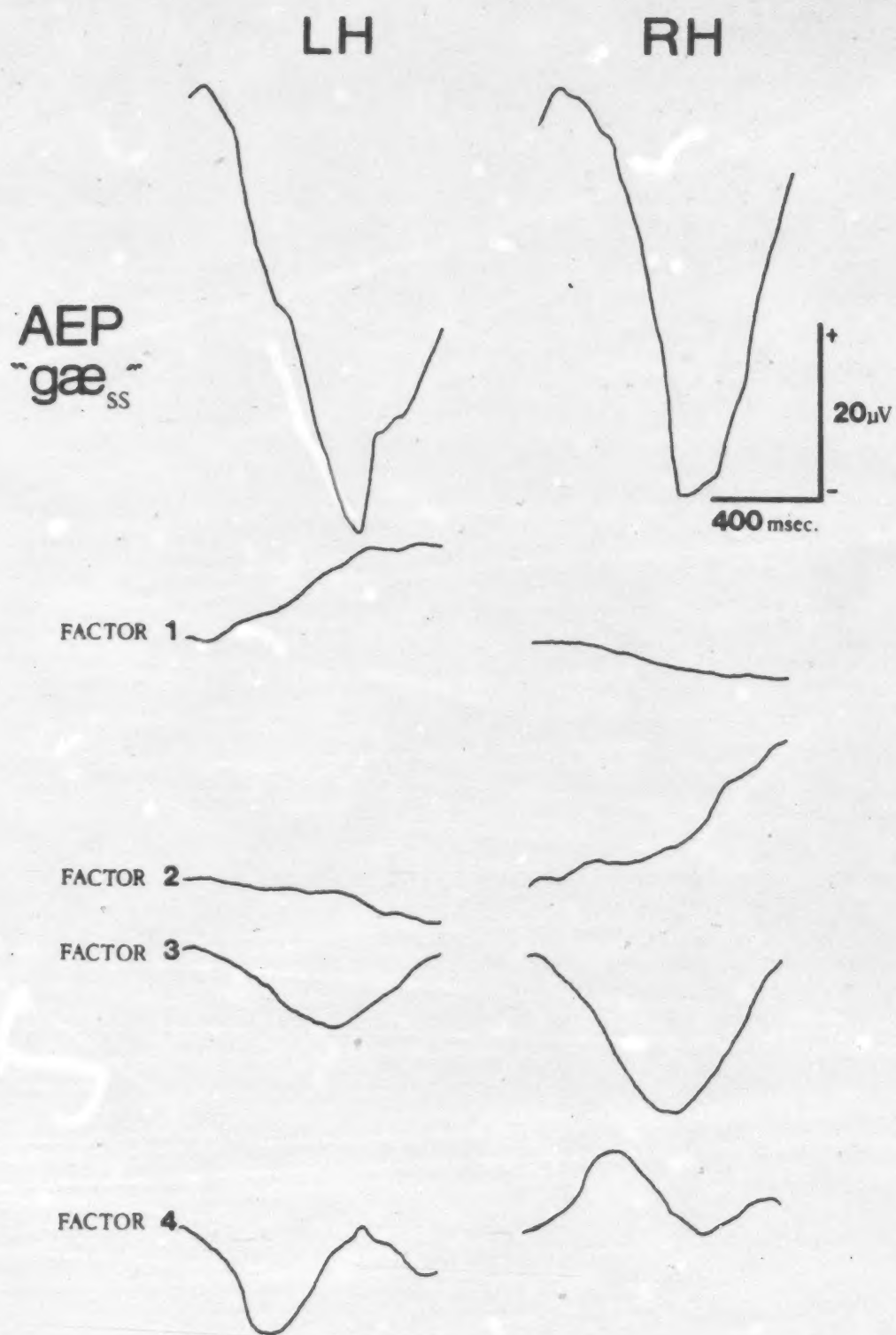
400 mSEC

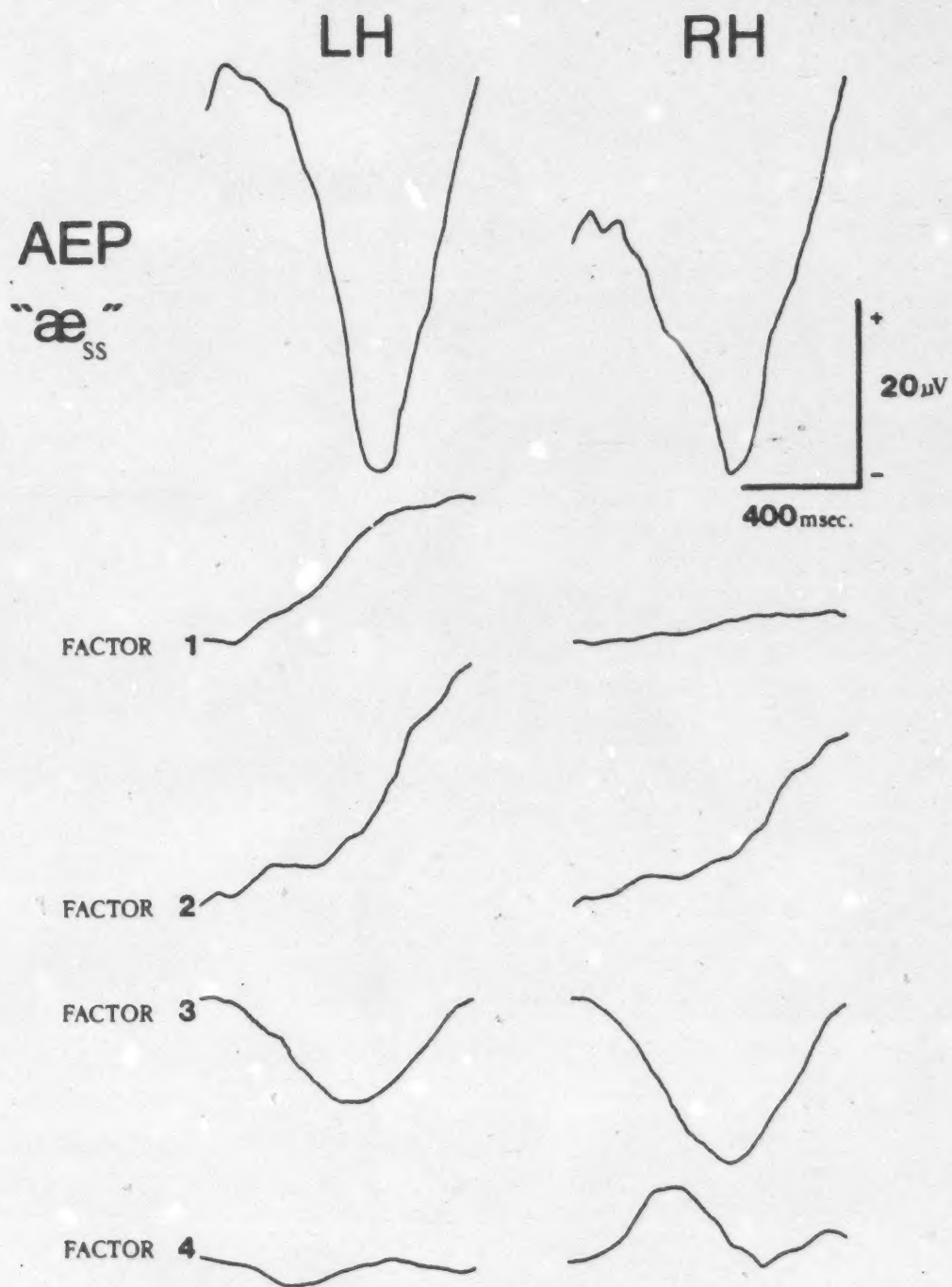
FACTOR 1

FACTOR 2

FACTOR 3

FACTOR 4





AEP
"gæ_{SW}"

LH

RH

400 msec.

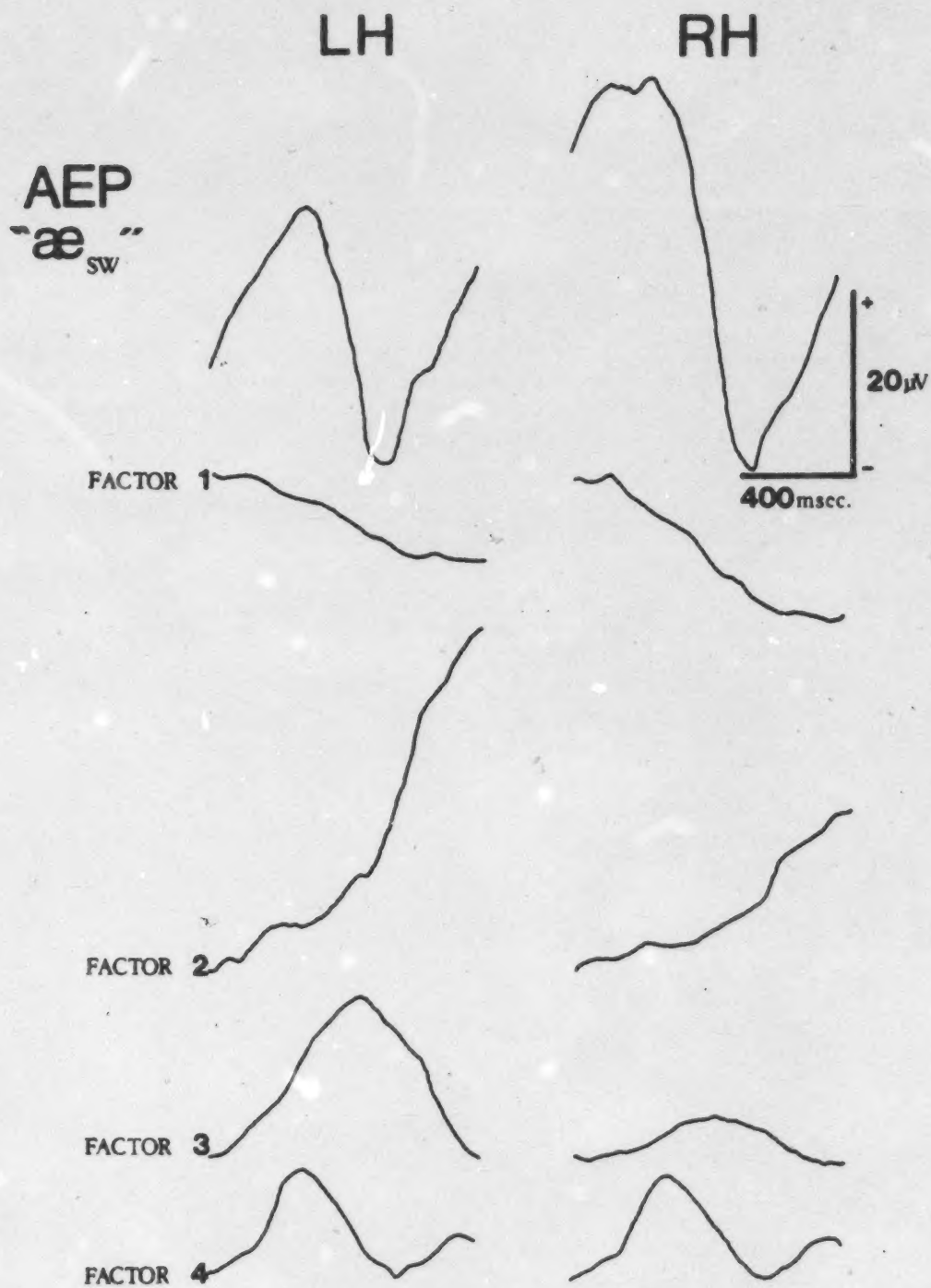
FACTOR 1

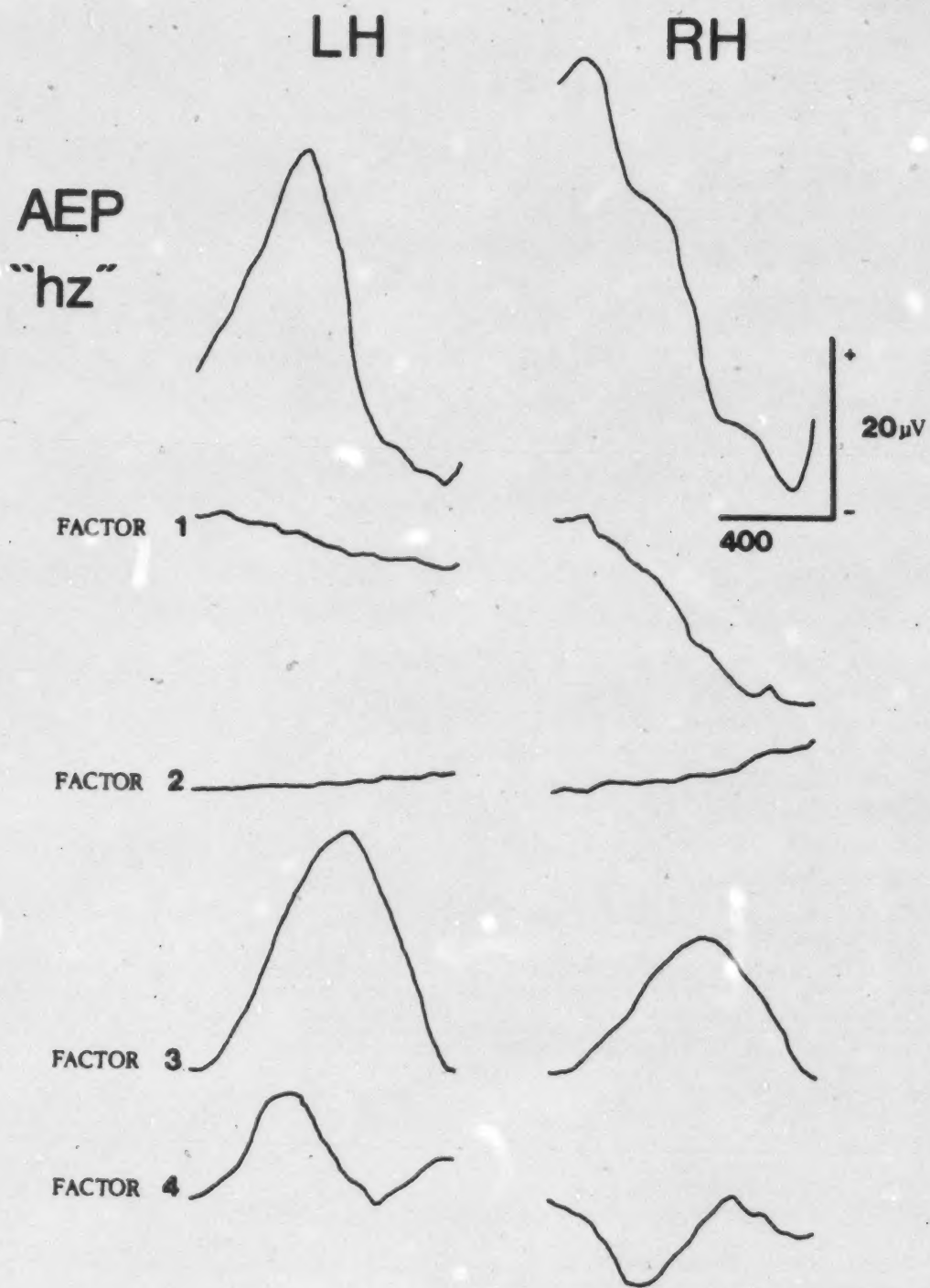
20 μ V

FACTOR 2

FACTOR 3

FACTOR 4



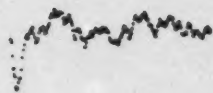


CAT II

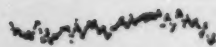
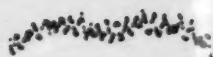
C_{SS}

C_{SW}

R/L IT



R/L V₁₈



30 μ V
+ -

500 MSEC